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(54) **PERSONNEL CLASSIFICATION AND RESPONSE SYSTEM**

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See application file for complete search history.

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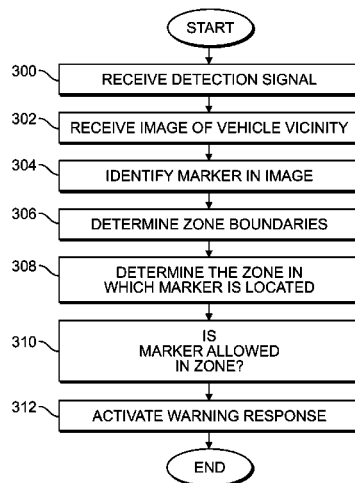|				
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(57) **ABSTRACT**

A personnel classification and response system, and related method and computer program product are disclosed. The system may comprise an image capture member and a controller connected to the image capture member. Some embodiments may also comprise a ranging apparatus. The ranging apparatus may be configured to provide a distance from a person to a vehicle. The image capture member may be configured to provide an image of the vicinity of the vehicle, the image including the person. The controller may be configured to identify in the image a marker and to activate a warning apparatus based on the marker and a zone in which the marker is disposed.
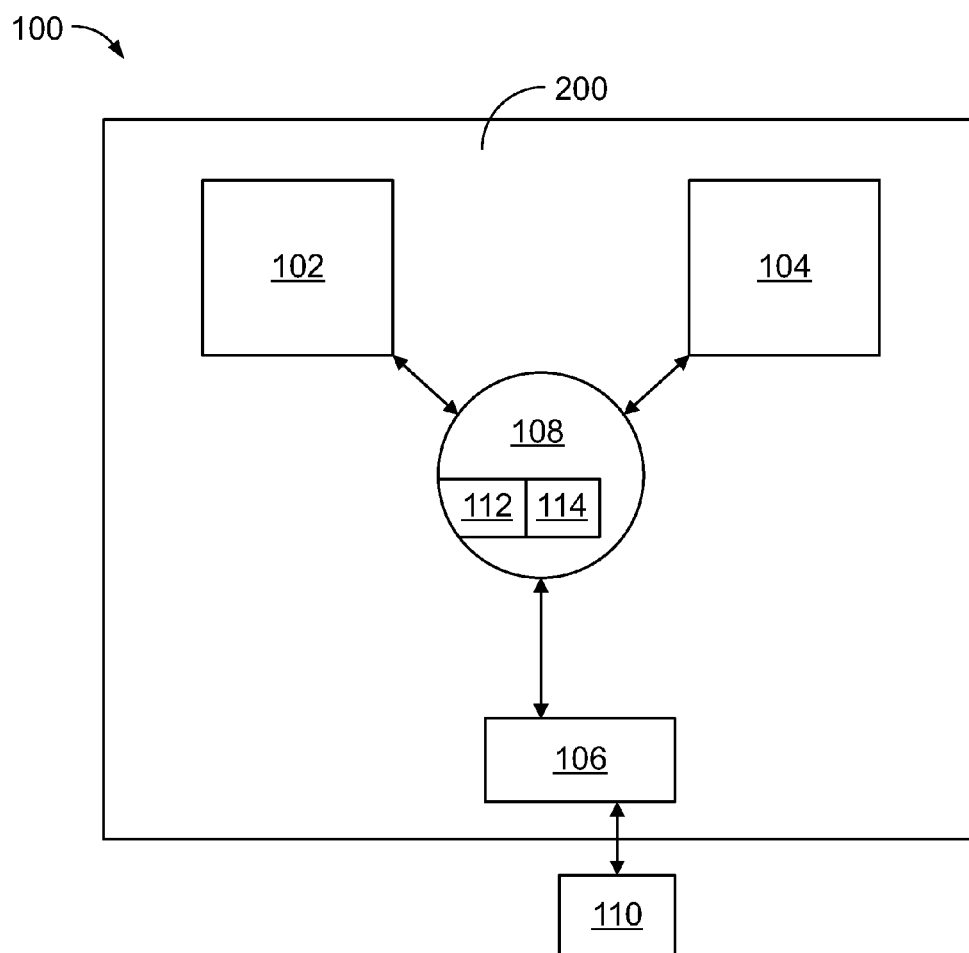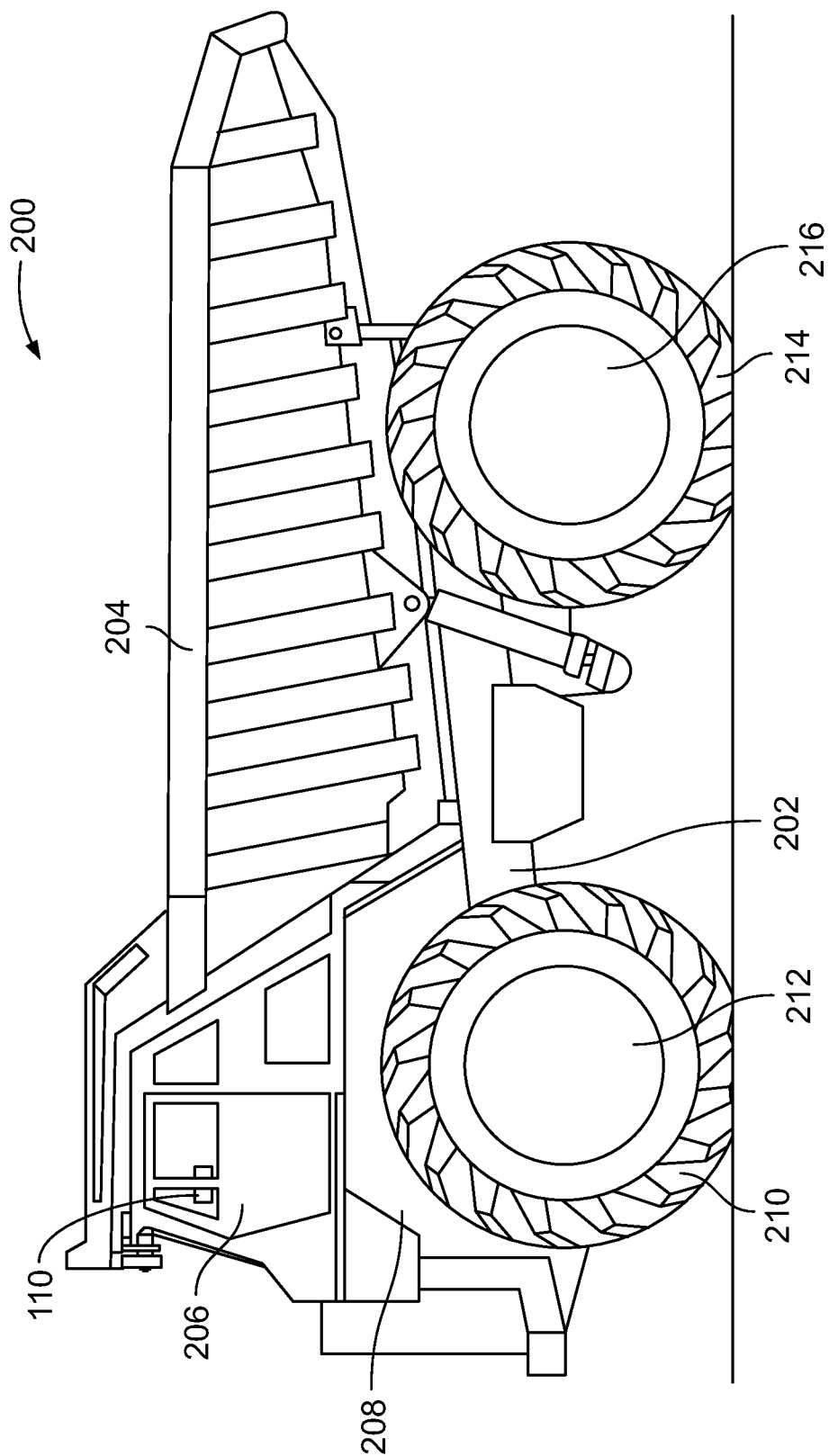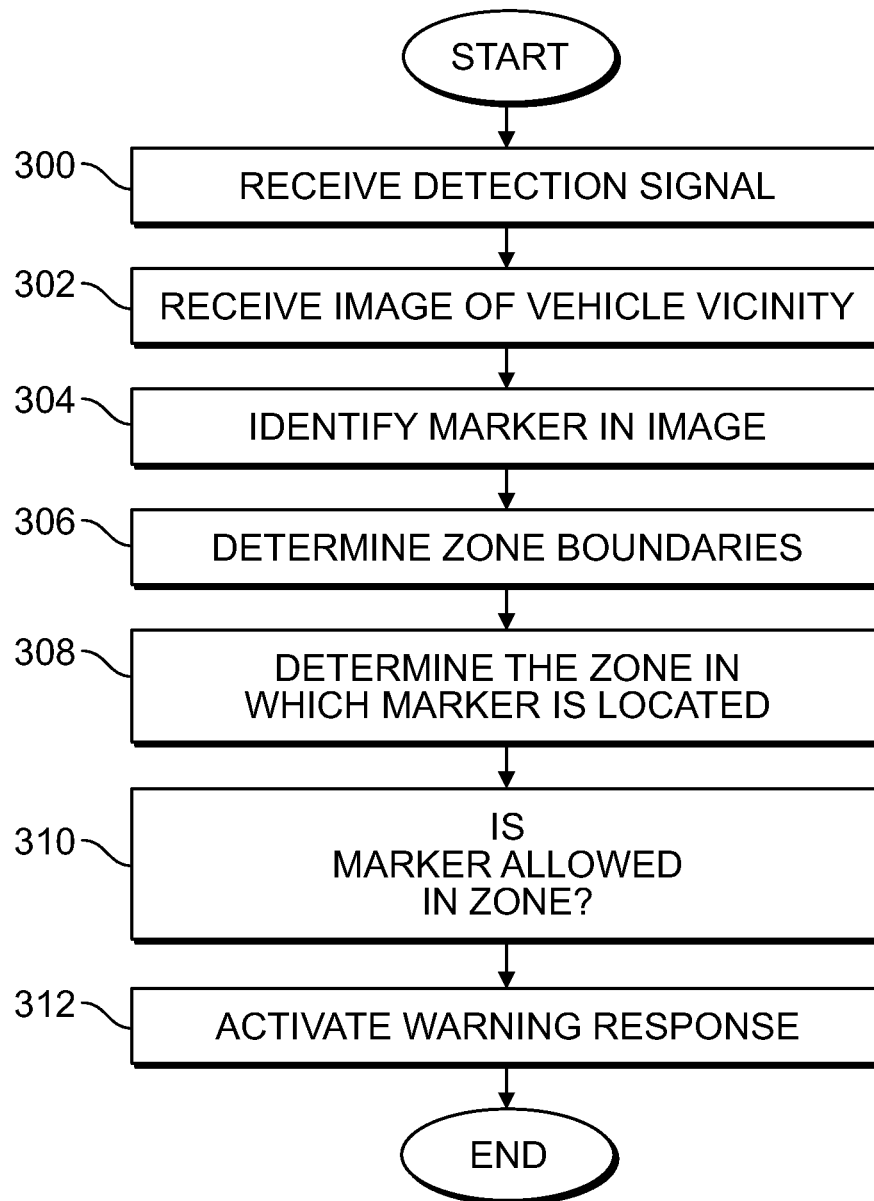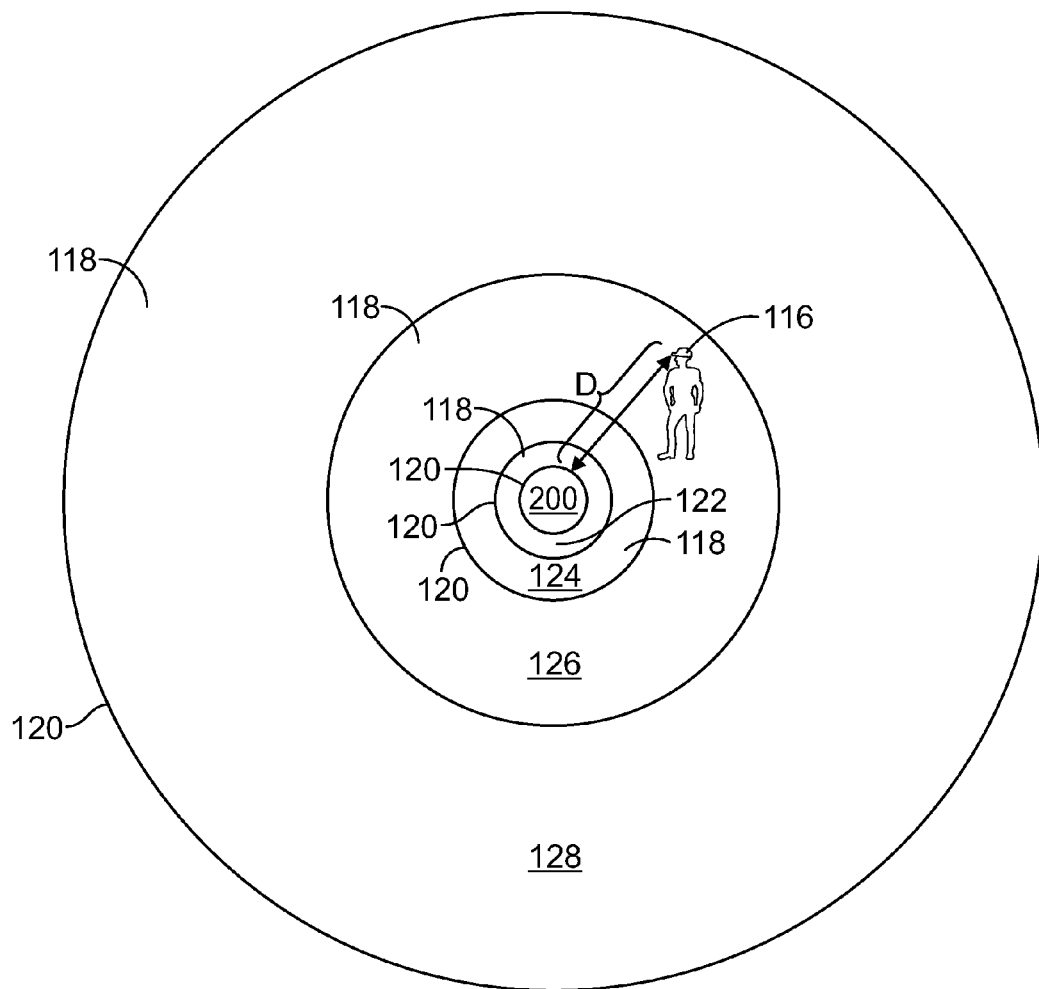
20 Claims, 6 Drawing Sheets

100

200

102

104

108

112 114

106

110

FIG. 1

FIG. 2

START

300 — RECEIVE DETECTION SIGNAL

302 — RECEIVE IMAGE OF VEHICLE VICINITY

304 — IDENTIFY MARKER IN IMAGE

306 — DETERMINE ZONE BOUNDARIES

308 — DETERMINE THE ZONE IN WHICH MARKER IS LOCATED

310 — IS MARKER ALLOWED IN ZONE?

312 — ACTIVATE WARNING RESPONSE

END

FIG. 3

FIG. 4
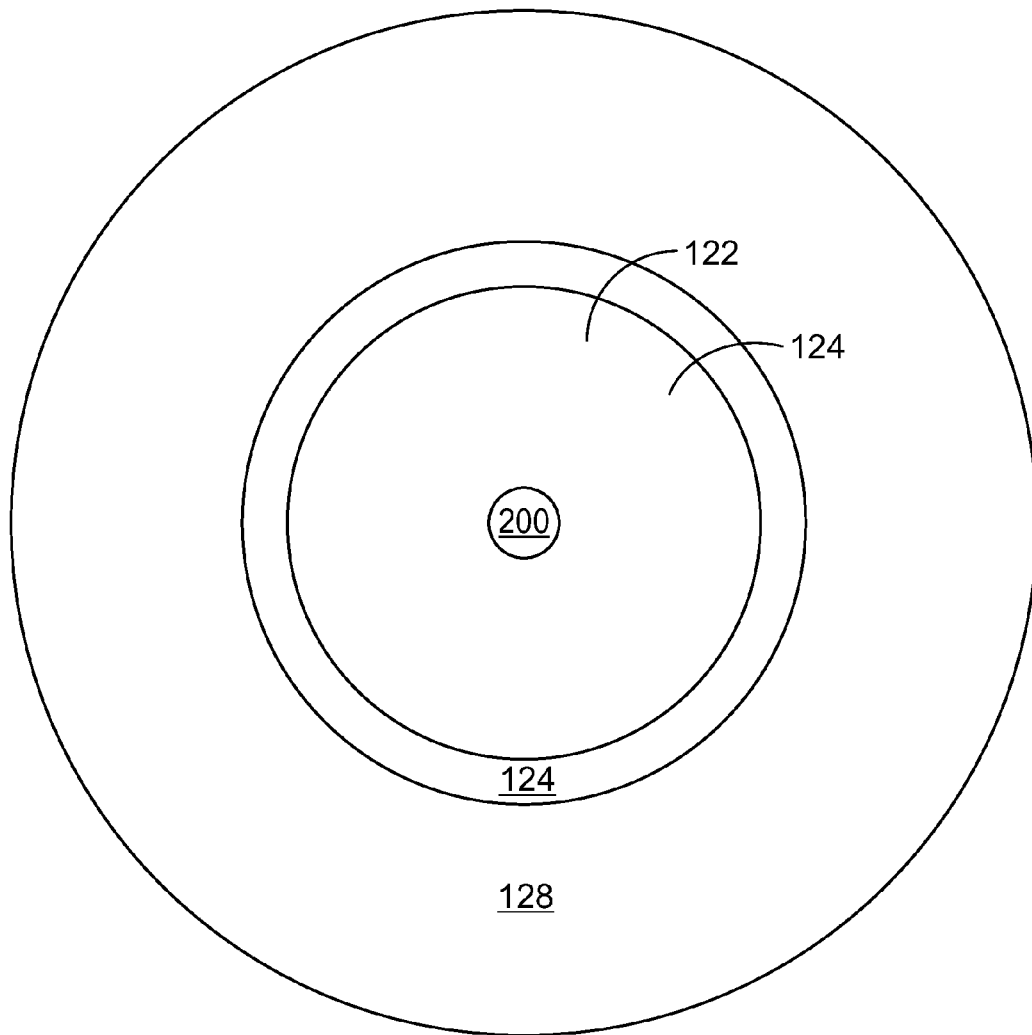
122

124

200

124

128

FIG. 5
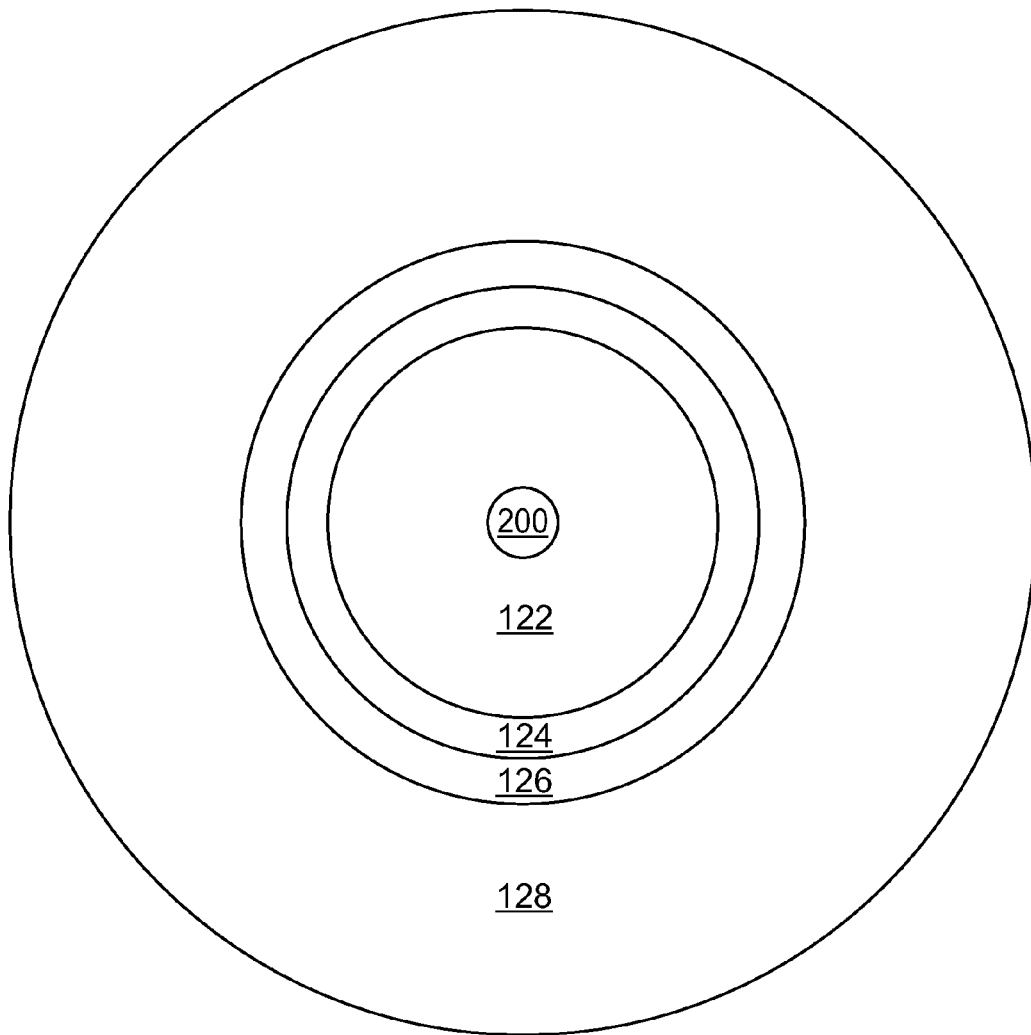
200

122

124

126

128

FIG. 6

PERSONNEL CLASSIFICATION AND RESPONSE SYSTEM

TECHNICAL FIELD

The present disclosure generally relates to warning systems and, more particularly, for such systems on vehicles used in mining, earth moving, construction, and material handling applications, and the like.

BACKGROUND

Vehicles in industrial applications may operate in work sites in which there are a variety of classes of personnel present. For example, on a worksite there may be experienced operators, new operators, engineers, supervisors, visitors, and the like. During typical operations, the different classes of personnel may be authorized to be within different distances to the vehicle. By way of illustration, a vehicle operator may be allowed within close range to a vehicle, whereas, a visitor may only be authorized to be within a more distant range of the vehicle. In some applications the vehicles may be autonomous, that is remote controlled or having programmed movement, and in other applications the vehicles may be semi-autonomous or manned. When the vehicles are autonomous, personnel straying too close to the vehicle may not be detected. In semi-autonomous or manned operations, the driver may not be able to distinguish between personnel authorized to be within a certain range of the vehicle and those that are not authorized.

U.S. Pub. No. 2010/0127853 published May 27, 2010 (the '853 Publication) discloses methods and apparatus for locating and tracking objects in a mining environment. The method discloses allowing mining personnel observing a display to see the positions of equipment and personnel. This type of system has drawbacks because of the visual clutter on the display that it provides. The system does not distinguish between the types of personnel and the zones around a machine in which it may be appropriate for the personnel to be present and the zones in which it is not appropriate. A better system is needed.

SUMMARY OF THE DISCLOSURE

In accordance with one aspect of the disclosure, a personnel classification and response system is disclosed. The system may comprise an image capture member and a controller connected to the the image capture member. The image capture member may be configured to provide an image of the vicinity of the vehicle, the image including a person. The controller may be configured to identify in the image a marker and to activate a warning apparatus based on the marker and the zone in which the marker is disposed.

In accordance with another aspect of the disclosure, a method of responding to a person in the vicinity of a vehicle is disclosed. The method may comprise processing an image of the vicinity of the vehicle to identify a marker disposed on the person, determining a zone in which the marker is present, and activating a warning apparatus based on the zone and the result of the processing step.

In accordance with a further aspect of the disclosure, a computer program product is disclosed. The computer program product may comprise a non-transitory computer usable medium having a computer readable program code embodied therein. The computer readable program code may be adapted to be executed to implement a method for responding to a person in the vicinity of a vehicle, the method comprising:

receiving a signal detecting the person at a distance from the vehicle, receiving an electronic image of the vicinity of the vehicle, the image including the person, processing the image to identify the color of a marker disposed on the person, the color associated with a personnel classification, determining a zone in which the marker is present based on the distance, and activating a warning apparatus based on the zone and the color of the marker.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a general schematic view of an exemplary embodiment of a personnel classification and response system constructed in accordance with the teachings of this disclosure;

FIG. 2 is perspective view of an embodiment of an exemplary vehicle in which a personnel classification and response system in accordance with the teachings of this disclosure is used;

FIG. 3 is flowchart illustrating exemplary steps of a method of responding to a person in the vicinity of a vehicle in accordance with the teachings of this disclosure;

FIG. 4 is a schematic of one embodiment of the zones around a vehicle, in accordance with the teachings of this disclosure;

FIG. 5 is a schematic of another embodiment of the zones around a vehicle, in accordance with the teachings of this disclosure; and

FIG. 6 is a schematic of another embodiment of the zones around a vehicle, in accordance with the teachings of this disclosure

DETAILED DESCRIPTION

Referring now to the drawings, and with specific reference to FIG. 1, there is shown a personnel classification and response system in accordance with the present disclosure and generally referred to by reference numeral 100. The personnel classification and response system 100 may comprise an image capture member 104, a warning apparatus 106 and a controller 108. In some embodiments, but not all embodiments, the personnel classification and response system 100 may include a ranging apparatus 102. In addition, in some embodiments, the personnel classification and response system 100 may also include a display 110 connected to the warning apparatus 106. The display may be disposed on the vehicle (as illustrated in FIG. 2) or remote from the vehicle (as illustrated in FIG. 1).

While the following detailed description and drawings are made with reference to the system 100 mounted on a haul truck, the teachings of this disclosure may be employed on other mining, earth moving, construction, material handling, or the like vehicles. Such vehicles may be autonomously, semi-autonomously, or manually operated.

FIG. 2 illustrates one example of a vehicle 200 that incorporates the features of the present disclosure. The vehicle may be autonomous, that is remote controlled or having programmed movement, or may be semi-autonomous (having partially remote controlled or programmed functions), or may be manually operated. The vehicle 200 generally includes a main frame 202, a dump body 204 pivotally mounted to the main frame 202, and a cab 206 mounted on the front of the main frame 202 above an engine enclosure 208. The vehicle 200 is supported on the ground by front tires 210 (one shown) each mounted on one of two front wheel assemblies 212, and rear tires 214 (one shown) each mounted on one of two back (driven) wheel assemblies 216. One or more

engines (not shown) may be housed within the engine enclosure **208** to supply power to the drive wheel assemblies **216** via a mechanical or electric drive train. In some embodiments, a user interface such as a display **110** may be disposed in the cab **206** of the vehicle **200**.

Turning back to FIG. **1**, the ranging apparatus **102** may be connected to the controller **108** and may be any appropriate type of ranging apparatus as is known in the art for detecting objects or people at a distance. Such ranging apparatus **102** may include, but are not limited to, systems and apparatus for radar, lidar, and the like. Generally, in embodiments that include a ranging apparatus **102**, some or all of the ranging apparatus **102** may be mounted to the vehicle **200**. However, in various embodiments, some or all of the ranging apparatus may be remote from the vehicle **200**. For example, a ranging apparatus **102** such as a Global Positioning System (GPS) may have some or all of its components remote from the vehicle **200**.

The ranging apparatus **102** may determine the distance, D (see FIG. **3**), at which a person is located in relation to the vehicle **200** and may transmit that information to the controller **108**. The ranging apparatus **102** may also provide to the controller **108** the direction the person is heading, the speed of the person and/or the altitude of the person. In one embodiment, the ranging apparatus **102** may be mounted on the vehicle **200** and may be a radar system that uses radio waves to determine the range, altitude, direction or speed of an object. Such a radar system may include one or more transmitters and one or more receivers mounted on the vehicle to provide desired detection coverage.

The image capture member **104** may be an optical apparatus having an optical lens or other imaging device or image sensor at one end and capable of capturing and transmitting images or videos through a communication channel to the controller **108** for processing. The communication channel may be an optical channel, or any other wired, wireless or radio channel or any other type of channel capable of transmitting images or videos between two points. In one embodiment, the image capture member **104** may be a camera. One or more image capture member(s) **104** may be mounted to the vehicle **200**. For example, in one embodiment, an image capture member **104** may be mounted to each of the four sides of a vehicle (front, back, left side and right side). In other embodiments, fewer or greater quantities of image capture members **104** may be utilized.

At least one warning apparatus **106** may be connected to the controller **108**. The warning apparatus **106** may include, but is not limited to, a visual display screen, a horn, lights, flashing lights, vibrator, buzzer or the like. A warning apparatus **106** may be a device that shuts off, slows down or temporarily halts the operation of a vehicle **200** or notifies the operator of the detection of a personnel marker **116** (discussed herein later). An auditory warning apparatus may increase the volume and or frequency of a warning sound with increasing proximity of a hazard. A visual warning apparatus may increase, on a display screen or vehicle, the number of activated warning lights, the brightness, color or frequency of flashing of the lights with increasing proximity of the marker **116**.

The controller **108** may include a processor **112** and a memory component **114**. The controller **108** may be operably connected to the image capture member **104** and the warning apparatus **106**. In embodiments that include a ranging apparatus **102**, the controller **108** may be operably connected to the ranging apparatus **102** as well. The processor **112** may be a microprocessor or other processor as known in the art. The processor **112** may execute instructions and generate control

signals for image processing, determining the vehicle zones **118**, classifying markers **116** and activating the warning apparatus **106** based on the marker **116** and the zone **118** in which it is present. Such instructions may be read into or incorporated into a computer readable medium, such as the memory component **114** or provided external to the processor **112**. In alternative embodiments, hard wired circuitry may be used in place of, or in combination with, software instructions to implement a control method.

The term "computer readable medium" as used herein refers to any non-transitory medium or combination of media that participates in providing instructions to the processor **112** for execution. Such a medium may comprise all computer readable media except for a transitory, propagating signal. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, or any other medium from which a computer processor **112** can read.

The controller **108** is not limited to one processor **112** and memory component **114**. The controller **108** may be several processors **112** and memory components **114**.

In one embodiment, the controller **108** may receive an image from an image capture member **104** and process the image (or series of images in a video feed) to identify a marker **116** in the image(s). In embodiments that include a ranging apparatus, the controller **108** may receive a signal or signals from a ranging apparatus indicating that a person has been detected at a distance, D, from the vehicle **200**. In some embodiments, this information (distance D) may be used by the controller **108** to assist with processing of the image to identify the marker **116** in the image. The controller may also be configured to retrieve from the memory **114** the machine zones **118** and zone boundaries **120** for a set of machine parameters, to classify the marker **116**, and to activate a warning apparatus **106** based on the marker **116** and the zones **118** in which it is present.

Industrial Applicability

Referring now to FIG. **3**, an exemplary flowchart is illustrated showing sample steps which may be followed in detecting personnel, classifying such personnel and responding to the proximity of such personnel. The method may be practiced with more or less than the number of steps shown and is not limited to the order shown. Step **300** of the method includes receiving, by a controller **108**, a signal indicating that a person has been detected in the proximity of a vehicle **200**. As noted previously, the signal may be provided by any appropriate type of ranging apparatus **102** known in the art for detecting people at a distance. Step **300** may also include receiving, by the controller **108** from a ranging apparatus **102**, a determination of the distance, D, at which the person is located in relation to the vehicle **200**. In an alternative embodiment, the distance D may be calculated by the controller **108** based on information received from the ranging apparatus **102**. In some embodiments, the controller **108** may also receive from the ranging apparatus information related to the direction the person is heading, the speed of the person and/or the altitude of the person.

In step **302** an image is received by the controller **108** of the vicinity of the vehicle. The image may include the detected person. The image may be received from the image capture member **104**. The image may be a single image or may be multiple images in a video feed. In embodiments that do not include a ranging apparatus, step **300** may be skipped and the method may begin at step **302** with an image received by the controller **108** of the vicinity of the vehicle, the image including a person.

In step **304**, the image is processed by the controller **108** to determine whether a marker **116** is present in the image. This processing may be done using known technology. For example, algorithms using part based models, such as the "Deformable Parts Model," and the like, may be utilized. Other appropriate algorithms may also be used.

In one embodiment, one or more segments of the image may be processed to determine whether a marker **116** is present in the image. For example, information received from the ranging apparatus **102** related to the distance, D, at which person was detected may be utilized by the controller **108** to identify a segment of the image for processing. The controller **108** may then process that segment of the image to determine whether the marker **116** is present. Alternatively, the entire image may be processed to determine whether the marker **116** is present.

The marker **116** may be an object, label, tag, geometric symbol or pattern, bar code, QR code, or the like. The marker **116** may be colored, black and white, grey tone, or reflective. The marker **116** may be disposed on an object carried or worn by the person. For example, the marker **116** may be a colored helmet or vest worn by the person. In the example of a colored helmet marker **116**, the controller **108** may process the image to identify whether a helmet is visible in the image and the color of the helmet. Pixel sampling, thresholding, or other methodologies known in the art may be used to determine the color of the marker **116**.

Once the marker **116** has been identified as visible in the image, the method proceeds to step **306**. In step **306**, the zones **118** around the vehicle **200** are determined by the processor **108** for a set of vehicle **200** parameters.

Each vehicle may have one or more zones **118** associated with it. FIG. **4** illustrates a vehicle **200** with four zones **118** around it. In the embodiment illustrated in FIG. **4**, the zones **118** are generally concentric, although they do not need to be concentric in shape and relation to each other. In other embodiments, there may be a greater or lesser number zones **118** associated with the vehicle **200**. The controller **108** may be configured to utilize a lookup table, or the like, to determine the number of zones **118** for the vehicle **200** and the boundaries **120** of those zones **118**.

The boundaries **120** of a zone **118** may vary depending on one or more of the following vehicle parameters: the type of vehicle **200**, the operational mode of the vehicle (autonomous, semi-autonomous, or manual), and the functional mode of the vehicle (e.g., parked, traveling, digging, cutting). The functional mode choices may be based on the type of vehicle **200** and its attachments. In some embodiments, the range of a particular zone **118** may also vary depending on vehicle parameters such as the travel speed of the moving vehicle **200** and whether the vehicle **200** is loaded, partially loaded, or empty. A plurality of vehicle parameters use to determine applicable zone **118** boundaries **120** for a vehicle **200** may be referred to herein as a set of vehicle parameters.

For example, as illustrated in FIG. **4**, there may be four concentric generally ring shaped zones **118** defined for an autonomous haul truck **200**. When the vehicle **200** is in an unloaded state, having an autonomous operational mode and a parked functional mode, the first zone **122** may extend from about 0 meters to about 5 meters from the vehicle **200**, the second zone **124** may extend between about 5 meters to about 10 meters from the machine **200**, the third zone **126** may extend between about 10 meters to about 40 meters, and the fourth zone **128** may extend between about 40 meters to about 100 meters from the vehicle **200**. Whereas, as illustrated in FIG. **5**, when the autonomous haul truck **200** is fully loaded and traveling (functional mode) at a speed between 3.5 m/s to

about 6 m/s, the zone **118** boundaries **120** change from that illustrated in FIG. **4** such that the first zone **122** may now extend from about 0 meters to about 50 meters, the second zone **124** may overlap the first zone **122** and extend between about 0 meters to about 50 meters, the third zone **126** may extend between about 50 meters to about 70 meters, and the fourth zone **128** may extend between about 70 meters to about 100 meters.

In the next example illustrated in FIG. **6**, the operational mode for the haul truck **200** is manned instead of autonomous, and while there may be still four zones **118**, the boundaries **120** of the zones **118** may be different than in the previous scenarios. The haul truck **200** is still fully loaded and traveling (functional mode) at a speed between 3.5 m/s to about 6 m/s. The first zone **122** may now extend from about 0 meters to about 30 meters, the second zone **124** may extend between about 30 meters to about 40 meters, the third zone **118** may extend between about 40 meters to about 50 meters, and the fourth zone **128** may extend between about 50 meters to about 100 meters.

In step **308**, the controller **108** identifies the zone **118** in which the marker **116** is present. The identification of the zone **118** may be based on the distance, D, of the marker **116** from the vehicle **200**. The distance D, if not provided by or calculated from information provided by the ranging apparatus, may alternatively be determined by the controller in step **304** as part of the image processing.

In step **310**, the controller determines whether the marker **116** is allowed in the zone **118**. Each zone **118** may have one or more markers **116** mapped to it. Each marker **116** may be associated with a personnel classification. For example, in one embodiment, there may be four personnel classifications each with a different color of marker **116** associated with it: vehicle operators, onsite engineers, new operators, supervisors and visitors. In other embodiments, there may be more or less or different personnel classifications. Personnel at a work site may be asked to wear or visibly display a marker **116** that is associated their appropriate personnel classification. This allows the controller **108** to identify the classification of the person in the image based on the marker **116** disposed on him and to customize the warning response based on the zone **118** in which the person is located. In other embodiments, each personnel classification may be associated with a different bar code or QR code, or geometric symbol, or the like.

In one embodiment, a marker **116** associated with an onsite engineer classification may be mapped to all zones **118** (meaning, the on-site engineer is allowed in all zones **118** around the vehicle **200**). A marker **116** associated with a vehicle operator classification may also be mapped to all zones **118**. A marker associated with new operator classification may be mapped to all zones **118** except the first zone **122**, a marker associated with the supervisor classification may be mapped to all zones except the first and second zones **122**, **124**, and a marker **118** associated with the visitor classification may be mapped only to the fourth zone **128**.

In step **312**, the controller **108** determines the appropriate warning response, if any, based on the marker **116** and the zone **118** in which the marker **116** is present. The controller **108** may utilize a look up table or hash table or other structure to determine the warning response. The controller **108** may then activate the warning apparatus **106** based on the marker **116** and the zone **118** in which it is located.

For example in an embodiment based on the autonomous haul truck **200** scenarios (FIGS. **4-5**) discussed above, if the marker **116** is in the first zone **122** and the marker **116** is associated with a visitor classification, the controller **108** may cause the warning apparatus **106** to shut off the operation of

the vehicle 200 because the marker 116 associated with the visitor classification is not mapped to the first zone 124. However, if the marker 116 associated with the visitor classification is present in the fourth zone 128 (an allowed zone, in this example, for the visitor classification), no warning action may be taken, or alternatively, the controller 108 may cause the warning apparatus 106 to activate a video image on a display 110 (a remote display, in this embodiment) and highlight the marker 116 on the image displayed.

In yet another embodiment, the controller 108 may cause the warning apparatus 106 to activate a bar graph on the display 110 indicating how relatively close the marker 116 is to entering a zone in which the marker 116 is not allowed. Alternatively, or in addition to, the controller 108 may cause the warning apparatus 106 to activate warning lights or buzzers on the vehicle 200. In scenarios where the vehicle 200 is manned, the controller 108 may, in some embodiments, cause the warning apparatus 106 to activate a video image on a display 110 inside the cab 206 of the vehicle 200 and highlight the marker 116 on the image displayed and/or activate a bar graph on the display 110 indicating how relatively close the marker 116 is to entering a zone in which the marker 116 is not allowed. Other types of warning actions may be taken instead of or in addition to the above.

Also disclosed is a computer program product, comprising a non-transitory computer usable medium having a computer readable program code embodied therein, the computer readable program code adapted to be executed to implement a method for responding to a person in the vicinity of a vehicle, the method comprising receiving a signal detecting the person at a distance from the vehicle, receiving an electronic image of the vicinity of the vehicle, the image including the person, processing the image to identify the color of a marker disposed on the person, the color associated with a personnel classification, determining a zone in which the marker is present based on the distance, and activating a warning apparatus based on the zone and the color of the marker.

The features disclosed herein may be particularly beneficial for use with autonomous, semi-autonomous and manned mining, earth moving, construction or material handling vehicles.

What is claimed is:

1. A personnel classification and response system comprising:

an image capture member that provides an image of the vicinity of a vehicle, the image including a person and a marker disposed on the person; and

a controller connected to the image capture member, the controller configured to identify in the image the marker and to activate a warning apparatus based on the marker and a zone relative to the vehicle in which the marker is located.

2. The personnel classification and response system of claim 1, wherein the marker is a colored marker and the controller is configured to determine the color of the marker and to activate a warning apparatus based on the color of the marker and the zone in which the marker is disposed.

3. The personnel classification and response system of claim 2, wherein the color of the marker is associated with a personnel classification.

4. The personnel classification and response system of claim 1, wherein the warning apparatus stops operation of the vehicle if the marker is not allowed in the zone.

5. The personnel classification and response system of claim 1, wherein the controller is configured to determine a first boundary range for the zone based on a first set of vehicle parameters.

6. The personnel classification and response system of claim 5, wherein the controller is configured to determine a second boundary range for the zone based on a second set of vehicle parameters, the first boundary range different from the second boundary range and the first set of vehicle parameters different from the second set of vehicle parameters.

7. The personnel classification and response system of claim 1, further comprising a ranging apparatus connected to the controller, the ranging apparatus configured to provide a distance from the person to the vehicle, wherein the vehicle is an autonomous vehicle.

8. A method of responding to a person in the vicinity of a vehicle, the method comprising:

processing an image of the vicinity of the vehicle to identify a marker disposed on the person;

determining a zone relative to the vehicle in which the marker is present; and

activating a warning apparatus based on the zone and the result of the processing step.

9. The method of claim 8, in which the processing step further includes identifying the color of the marker.

10. The method of claim 9, wherein the color of the marker is associated with a personnel classification.

11. The method of claim 9, wherein the warning apparatus stops operation of the vehicle if the marker is not allowed in the zone.

12. The method of claim 11, wherein the vehicle is an autonomous vehicle.

13. The method of claim 9, wherein the warning apparatus slows operation of the vehicle if the marker is not allowed in the zone.

14. The method of claim 9, wherein the warning apparatus causes the image to be displayed on a display if the marker is not allowed in the zone.

15. The method of claim 14, wherein the warning apparatus causes the marker to be highlighted in the image displayed if the marker is not allowed in the zone.

16. The method of claim 14, wherein the display is in the cab of the vehicle.

17. The method of claim 8, further comprising determining a boundary range for the zone based on a first set of vehicle parameters.

18. The method of claim 17, further comprising determining second boundary range for the zone based on a second set of vehicle parameters, the second range different from the first range.

19. The method of claim 17, further comprising receiving a signal detecting the person at a first distance from the vehicle, wherein the zone is determined based on the first distance.

20. A computer program product comprising a non-transitory computer usable medium having a computer readable program code embodied therein, the computer readable program code adapted to be executed to implement a method for responding to a person in the vicinity of a vehicle, the method comprising:

receiving a signal detecting the person at a distance from the vehicle;

receiving an electronic image of the vicinity of the vehicle, the image including the person;

processing the image to identify the color of a marker disposed on the person, the color associated with a personnel classification;

determining a zone relative to the vehicle in which the marker is present based on the distance; and

activating a warning apparatus based on the zone and the
color of the marker.

* * * * *